

THE EXTENSION PATHOLOGIST

A NEWS LETTER FOR EXTENSION WORKERS INTERESTED IN PLANT DISEASE CONTROL

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REPORT OF CONFERENCE* ON FIRE BLIGHT OF APPLES AND PEARS

The meeting was called to order by Chairman Luther Shaw, of North Carolina, with the following introductory remarks:

"A number of subjects have been taken up and discussed in a general way at these conferences, including seed treatment, which was discussed last year. At a meeting of our committee in Richmond last December, of the several subjects proposed for discussion at this meeting, there seemed to be unanimous agreement that fire blight would be the most desirable. Therefore, the subject of fire blight of apples, pears, and related crops has been chosen. An effort has been made to bring a group together with a few specifically asked to contribute to the program. However, I hope those of you who have not been specially asked to participate will enter into the discussion and make public your experiences with this disease.

"I have been chairman of the Extension Work and Relations Committee for 2 years. It has been somewhat difficult at times to see how we can best contribute to the progress and well-being of the Society. However, I think over a period of years, through conferences of the type we are about to have, we make definite contributions. The calling of this conference has not been for extension workers alone. It brings together both research and extension workers, and it is the hope that both will contribute freely to the discussion and that mutual benefits will be derived.

"As I said before, I have asked a few to give their experiences specifically. First I should like to ask Dr. E. M. Hildebrand, of Cornell, who has been actively engaged in fire blight work and who has made some very fine contributions to this work, to open the discussion."

Dr. E. M. Hildebrand (New York) - When I began work on fire blight at the suggestion of my chief, Dr. L. M. Massey, several years ago, I was seriously under the impression that everything of importance was known about this disease. After spending about 7 years on it, the final solution to the problem of fire blight still seems far away. However, at a conference such as this, what seems to me to be much more important than knowing all the facts about fire blight is the interpretation and presentation of

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the known facts so that the grower will use them to best advantage. In New York we have made an attempt to teach our growers the complexity of the fire-blight disease and its control in a popular bulletin.^{1/} In order to show the life history of the causal organism in the briefest possible way, cartoons were used to tell the story of the organism, accompanied by a concise discussion of the known facts. Because our growers have reacted very favorably to this publication, in opening my discussion I am taking the liberty to show some slides taken from the above bulletin. (Slides of the cartoons illustrating the life history of the fire-blight organism were shown.)

From the life history of the fire-blight organism, it is apparent that there are two, or possibly three, well-known periods when the bacteria are particularly amenable to control measures. These are the dormant canker phase, the active canker phase about blossom time, and the active canker phase during the remainder of the growing season.

Dormant Canker Phase

In combating fire blight during the dormant season several control measures can be applied for the removal or inactivation of dormant cankers, and I still would recommend the surgical method until something better has been found. We have tried chemical paints and the acetylene torch along with the surgical method and are convinced that during the dormant season the surgical method, if carefully done, is more effective than any other method. There are advantages and disadvantages to the method, as everyone knows.

The chief difficulty we encounter with growers during the dormant season is concerned with the kind of cankers to eradicate. In keeping with long-established precedent, we customarily recommend the removal or inactivation of all cankers, since there is no practicable way of telling which cankers will survive the winter. When asked where to draw the line, we research and extension men keep on the safe side by leaving the decision up to the growers; and more often than you may realize the average grower gives up in disgust and does little or nothing about canker removal. It is difficult for even the very best growers to eliminate all the primary inoculum, presumably only confined to dormant cankers. It seems that despite the best of efforts there is always sufficient inoculum to produce an epidemic when weather conditions are favorable. Perhaps one reason for our inadequacy in this regard is that we have a tendency to place entirely too much reliance on canker eradication for the control of the disease. My belief is that the grower, when educated to the complexity of the disease, will not think of blight control in terms of canker eradication alone but will broaden his program of attack and will be receptive to the idea of preventive measures.

I have observed that usually when pear trees are lost from blight, entry of the pathogen into the plant had taken place through either blossom

^{1/} E. M. Hildebrand. Fire blight and its control. N. Y. Agr. Coll. (Cornell) Ext. Bull. 405, 32 pp. illus. Ithaca. 1939.

spurs or succulent shoots located in the more vital parts of the trees. An excellent preventive treatment to be recommended during the dormant season is the removal of fruit spurs from the trunk and scaffold branches. This measure alone might conceivably do as much good as the blanket recommendation of canker eradication.

Active Canker Phase

Next, turning to the growing season, I should like to mention a number of preventive treatments. One of these is protection of blossoms from infection by spraying or dusting in bloom. If this is done properly, the proper materials used, the treatments timed right, and thorough coverage made, blossom infection may be reduced as much as 90 percent or more. If analyzed on the basis of the reduction in number of spurs infected, it may be only 60 or 70 percent; and obviously there is considerable injury despite the treatment. A single treatment may protect no more than 50 percent of the blossoms and two treatments no more than 80 percent. Perfect control is the ideal. We have tried spraying or dusting in bloom every day for as many as 5 or 6 consecutive days and obtained approximately perfect control, but this is out of the question from a practical standpoint. The open-blossom treatments, therefore, should not be considered as a cure-all but rather as another step in carrying out a preventive program.

Another preventive method worth mentioning that is now in the experimental stage is the use of special spray materials for preventing or reducing fruit set, particularly on young trees. If such a treatment can be perfected, it should prove of much benefit from the blight-control standpoint, especially in young orchards which are more susceptible to blight than older trees and from which fruit is not wanted. Bearing trees with a tendency to the biennial habit may profitably receive such a treatment also to aid in blight control by reducing fruit set, which practice could conceivably eliminate need for thinning.

Control of the insect population is another preventive measure. One possibility is the removal of pollinating insects when sufficient cross-pollination has occurred. This practice can be employed where the pollinating insects are imported. Based on the latest information available, from 1 to 2 days of good pollination weather are sufficient to insure a commercial set of fruit.

A method for the reduction of sucking insects to prevent secondary spread of the parasite is now under experiment. The essence of this method is the use of a dormant spray for the control of aphids and leaf-hoppers both of which overwinter as eggs on the trees. Elgetol, the most promising material thus far obtained, also seems to offer promise for inactivating the overwintering cankers as well.

Simple as it is to remove sucker growth during the growing season, how many growers do it? Usually the best growers neglect to do it. This is an important measure to use on all ages of pear trees and is especially recommended on all the more highly susceptible apple varieties, and it

should be done early before the growth has become woody. This is also an excellent sanitary measure. In my opinion, we should put more emphasis on such simple preventive measures; and it is the job of the research and extension men to get the growers to use such measures.

Bactericidal summer sprays for reducing shoot infections, I presume, will be discussed by Dr. Keitt, the next speaker.

Cultural practices which do not overstimulate the trees also deserve mention. After several seasons with no blight, growers become careless and fertilize too heavily.

We should strive to get away from recommending the use of surgical methods during the growing season because most growers are not sufficiently skilled to do the job without hazard. When cankers develop in the summer despite the use of the aforementioned preventive treatments or, as is usually the case, because very little has been done, I believe this is the place where chemical paints may best be used. Any one of the three paints mentioned in the extension bulletin, if applied to the first stages of canker development at the base of a spur or shoot, should inactivate a high percentage of the cankers; and if it fails to stop activity after one application it should be used a second time. Where cankers are extremely abundant, emphasis should probably be placed on the control of those in the vital parts of the trees, letting the others go until the next dormant season.

In summarizing my remarks, I wish to make but one point, and that is the favor with which our New York growers are receiving the bulletin already mentioned. The same idea may apply to other diseases as well. If the use of cartoons will make the grower realize that the fire-blight organism is in the cankers at all seasons and ready to do damage at every opportunity, then they have succeeded in doing a worth-while thing.

Dr. Shaw--I should like to call on Dr. Keitt for his paper on "Epidemiology of Fire Blight."

Dr. Keitt read his paper which is published in full at the end of these notes.

Dr. Shaw--The meeting is now open for discussion. I should like to ask Dr. Anderson of Illinois for questions on Dr. Keitt's paper.

Dr. H. W. Anderson (Illinois)--One thing which I have observed in past years is that we are likely to have an outbreak of fire blight with a season of heavy bloom on the trees and fine pollinating weather during bloom. This is just an observation and has not been checked. Referring to Dr. Keitt's talk, I should like to ask whether the vigor of the tree makes any difference where blossom blight is concerned, whether we may have blossom blight where the vigor of the trees is poor or whether it is very much more severe in vigorous trees?

Dr. G. W. Keitt (Wisconsin)--I agree with Dr. Anderson. I think that if the tree is vigorous there is much more danger of spread than if the tree is low in vigor.

Dr. Anderson--Dr. McCown from Indiana is here, and they had considerable blight in Indiana this year. He was one of the earlier workers on sprays for fire blight. I should like to hear from Dr. McCown.

Dr. Monroe McCown (Indiana)--We have studied the use of weak bordeaux in early applications. We have a lot to learn, and perhaps a few remarks might be proper on the timing of these sprays under our conditions. We have various growers in Indiana who have been spraying in bloom to prevent fire-blight infection. Those who have been spraying regularly from season to season are, without exception, obtaining very good control. This is resulting in a reduction in carry-over. Men who have sprayed intermittently have had varied results. I do not think we can clean up fire blight in an orchard with one single spray. As to timing, I visited a number of orchards this season and tried to evaluate the results of spraying. Some of the growers had sprayed with very little effect, but the spraying had been done too late to be very effective.

Now as to the question of russetting. We have had serious russetting on certain varieties when weak bordeaux was applied at petal fall. We have not seen serious russetting follow the use of the spray during the period of opening of the flowers. I think that is a point to be emphasized in the spray schedule. If the spray is applied when 20 percent of the blossoms are open, one application will give us fair control under Indiana conditions. In some orchards where serious blight infection may occur, particularly on Jonathan and other varieties in which the wood as well as the flowers is very susceptible, I would spray two times--when 25 to 30 percent of the flowers are open and again when 50 to 60 percent of the flowers are open. So far as injury to the flowers is concerned, we have done a small amount of work on that with no reduction in set. Workers at Cornell have studied the effect upon set more thoroughly than we have.

Dr. Donald Cation (Michigan)--I would like to ask about the difference in sugar content in different nectars.

Dr. Keitt--Our investigations have been very limited and we have not gone far enough to answer the question satisfactorily.

Dr. Hildebrand--There is a man in Germany (Beutler, 1930) who has studied the concentration of nectar. He found that the pear secretes nectar with an average of about 20 percent sugar. Apple nectar was near this concentration also. We must keep in mind the effect of environment on nectar.

Dr. Cation--I analyzed nectar one season and it contained about 48 percent total solids, most of which was sugar. The way we did it was to take the bees on the blossom and squeeze out honey sacs and determine the percentage of solids with a refractometer. It was consistently about 47 to 48 percent. We were interested at that time to see whether bordeaux would materially lower the concentration of water in the nectar, and results indicated that it was lowered about 2 or 3 percent. We had one period of very light rainfall, and a few determinations made that day showed that the concentration of sugar dropped to 10 percent.

Dr. Keitt--Armbruster has reviewed much work on nectar of many plants. Our own work has been limited to apple and pear. There is great variability of the sugar content with moisture and other conditions.

Mr. J. B. Carpenter (Wisconsin)--In regard to suckers and their removal, is it permissible to rub them off when they are young or should they be pruned smooth?

Dr. Hildebrand--I would recommend using leather gloves and rubbing off the suckers at a time when they will come off easily.

Dr. Cation--I should like to find out whether one should break off twigs or cut them off. Is the wound resulting from breaking more vulnerable to infection than one resulting from a cut? The objection to cutting is the necessity for frequent disinfection of the shears.

Dr. Hildebrand--I would not cut, but would break twigs off if possible, mostly because growers are so careless in the use of pruning shears. Reinfestation may become a problem when using shears that are not disinfected. I have found growers who disinfected the shears every sixth cut.

Dr. Cation--We use a glycerine solution of mercuric chloride as a disinfectant.

Dr. Hildebrand--In New York we get no special benefit from the use of glycerine solution under our weather conditions, although I personally use it in Reimer's solution for disinfecting wounds.

Dr. H. N. Racicot (Ottawa, Canada)--We still recommend a mixture of glycerine, bichloride of mercury, mercuric cyanide, and water as a disinfectant. It does not evaporate or splash. It clings to the shears for a long time, penetrates the wood, and stays on the wood and on the surface for a long time. It is the best we have found; and we have tried Semesan, Semesan Bel, and mercuric iodide.

We have not tried to break off twigs. The only thing to do is to wait until the dormant season. If one does too much cutting of twigs there is a danger of prolonging the vegetative growth of the trees, resulting in greater susceptibility. We recommend glycerine and water as a disinfectant.

Dr. Shaw--Apple scab has definite critical periods, and predictions can be made of how serious the disease may be expected to be in a given year. Definite methods have been worked out for making such predictions. Dr. Keitt, what progress has been made in making predictions concerning the epidemiology of fire blight?

Dr. Keitt--We are not far enough along to be able to make very reliable predictions. It is possible to cite indications and probabilities, but fire blight is so varied in its epidemiology with seasonal conditions that it cannot be foretold in advance. Any prediction with any satisfactory degree of reliability is difficult. Trees that bloom vigorously are

more likely to be injured than trees that are out of bearing. If such matters are disregarded, I would hesitate to try to go far in making predictions.

The first year I worked in orchard pathology I knew a man who had several apple trees in his yard as ornamentals. They were so badly blighted that one could see their brown color from a quarter of a mile away. He also had a great many apple trees nearby. I advised him to take the ornamental trees out, but he valued them so much that he did not. Next year the trees did not have any blight.

Dr. Hildebrand--I had much the same experience. One time a fruit grower came to me and asked what to do about blight in his orchard. I had a dozen pruning shears and with as many high school boys started out and pruned all day, 13 of us. When the grower saw how much effort it took he said there would be no more of that. We pruned all the blight out of one row of trees. The next year the trees that were not pruned had a fair blossom and fruit set. The trees we pruned had no blossoms and blighted. I will never try to prune trees again where blight is so serious. It is very hard to tell where to draw the line on pruning.

Dr. Racicot--In Canada in some of our experiments we had more blight in our summer-pruned trees than in those pruned during the winter. As far as pruning is concerned, if there is a serious infection, it is far better to leave it alone until winter with the exception of keeping the water sprouts cut out so the infection will not get into the main trunk. The disease is one that has always puzzled me. One year a tree may be affected in one orchard, and the neighbor's trees may be free; and the next year the order may be reversed. One farmer may have severe fire blight and the neighbor none, although both have the same varieties; and the next year, vice versa. A number of factors operate to determine the amount of blight--time of rainfall, number of cankers on the tree, and whether the trees are producing or not. As far as pruning is concerned, the only time it can be to advantage is in the winter; and usually it is an advantage to prune in the winter. Our work in Quebec has never been properly completed because our problem solved itself very easily. Our varieties fall into two groups, McIntosh and those in the Russian group. McIntosh seedlings and roots are fairly resistant to fire blight. If varieties that have no commercial value, such as Alexander, were disposed of, as far as Quebec is concerned, the problem would be solved.

Dr. A. L. Pierstorff (Ohio)--I think the experiences in Ohio have been very much like those in other States. We have had most blight in good pollinating weather, especially when rainfall preceded. We have had the same experiences as the growers in Quebec. We do not recommend summer pruning on apples, but the practice is recommended in the few pear orchards that are left. We recommend fall pruning, starting September 1. We have had very good results when limbs which were badly blighted were pruned out. Growers are not so busy in the fall. We try to get growers to remove the suckers by rubbing them off.

Mr. H. F. Winter (Ohio)--In our experience with fire blight we have rather consistently noted that if a tree blighted seriously one year it ordinarily did not blight the next year. I have been wondering if some type of temporary immunity is developed which might carry over to the next year.

Dr. Keitt--Don't you think this is correlated with the off-year periods?

Mr. Winter--The first serious infection occurred in a year when there were plenty of blossoms. The next year the trees were so badly damaged that there could not be very many blossoms.

Mr. Carpenter--We have had similar experiences in years of abundant blossoming. One year Wealthy might be seriously affected with blight, but the next year it might recover. We have attributed this to the fact that the trees did not have the blossoms on off-blight years and so were not so vulnerable to blight.

Mr. Winter--I do not believe this can be tied up with the blossoms entirely. Blossom blight has been almost entirely absent in the particular orchard I have in mind.

Mr. Carpenter--It could happen to nonbearing trees such as Wealthy, which are forced into biennial bearing. In some orchards whole blocks of Wealthy will be devoid of blossoms one year, and the next year they will be full.

Dr. Hildebrand--In line with our own observations, most of the cankers that are formed by infection from suckers do not survive especially on the more resistant varieties. Alexander is extremely susceptible, however, and a considerable percentage of its cankers may overwinter. We have also observed that in the bearing year the blossoms become infected and in the off year there will be little or no blight.

Dr. Pierstorff--We have observed that frequently we get blight in the southern part of the State (Adams County) on such varieties as Yellow Transparent, with no left-over cankers to show that the disease was present during the previous year.

Dr. Keitt--Where this is clear it is probable that inoculum was brought in from a fairly remote orchard. I have in mind a certain small, comparatively isolated home orchard in Wisconsin. We searched for overwintering cankers and found none, but there was clear evidence that a few scattered blossom clusters had been infected in an early stage and that secondary blossom infection was traceable to them. Where the primary inoculum came from I would be unable to say, but I would guess that bees or other insects brought it in.

Dr. Shaw--I should like to get an estimate from each State of the extent of full-bloom spraying as a means of fire-blight control. As far as I know there are no records on this question. Dr. Hildebrand, how extensive would you say full-bloom spraying is in New York State?

Dr. Hildebrand--We do not have any reliable way of telling. I know it has been done in a number of places and for a number of years. A 100-acre plot on which blight started in 1933 has been dusted each year since, and the blight has been eliminated for all practical purposes. There are some areas where spraying is used extensively after blossom blight has been severe one season, but there is a let-up when there is no recurrence of the disease for several seasons.

Dr. Keitt--Spraying in bloom is not practiced extensively in Wisconsin. We do not have extensive apple culture in southern Wisconsin where the disease is more likely to occur.

Dr. McCown--Like Dr. Hildebrand, I cannot make any definite estimate. It will vary considerably. In some orchards spraying is consistently practiced. I am glad that Dr. Hildebrand made the comment he did about the effect of these sprays over a period of years. The cumulative effect is very important.

Dr. Pierstorff--Not much spraying is done in Ohio. Dr. McCown's father was the first one to spray. I do not know whether growers spray any more or not.

Dr. McCown--Growers sprayed consistently for 15 years, beginning in 1912 or 1915. My father sprayed to keep the bees away, using arsenate of lead and bordeaux because he thought the bees were bringing in the blight.

Dr. C. F. Taylor (West Virginia)--A few growers in West Virginia, not more than half a dozen, spray Transparent in full bloom and appear to believe in it since they do it every year.

Mr. H. W. Rankin (Pennsylvania)--The only full-bloom sprays put on this year were on a demonstrational basis. I do not know of any grower who sprays as a general practice.

Dr. G. M. Armstrong (South Carolina)--Nothing to report.

Dr. M. W. Gardner (California)--This disease is known as pear blight in California. Very few of our growers are spraying in full bloom. The blossoming period may be very long, even 3 to 4 weeks, following mild winters. It is a standard practice to cut out cankers.

Dr. Racicot--I have been interested in these reports. Most reports of full-bloom spraying give only 1 year's results. I should like to have someone do the experiment properly. We have sprayed at 350-pound pressure and dusted with a hand duster, but after spraying and dusting we have atomized the blooms with inoculum and obtained about 20 percent infection in the blossoms. We examined these blossoms with a hand lens and found that these blossoms were only partly open and did not receive any spray on the inside, even with 350 pounds pressure. Some of the blossoms in the cluster opened so late that two or three sprayings would have been required. I am rather skeptical about the value of spraying in full bloom. However, I have an open mind and should like to have this thing

settled one way or another. I should like to have some of the people here who are working in a district where there is fire blight carry out some experiments and give us real data. There is so much chance of trees not having fire blight for a year, or 2 years, and of not leaving any checks. This gives data which is entirely misleading.

Dr. Cation--As far as spraying is concerned, I know of only one grower who is consistently using the fire-blight spray. He has Tolman Sweet and King and he is getting fairly consistent control of blossom blight with this spray program, and every year he leaves one tree as a check. A tree of Tolman Sweet which he left one year was almost 100-percent blighted. We have had most of our experiments when there was not much blossom blight. Where blight is severe we usually tell the growers to cease cultivation and put the orchard in sod. I know of one apple orchard of Wagner, Wealthy, and Jonathan which was overcultivated and which had a little blight. Because of an erosion problem in the orchard, a sod mulch was established. A tremendous blight problem developed because of the increased humus content of the soil. Sometimes we do not have a blight problem in certain pear orchards in Michigan because of continued clean cultivation which causes the soil to lose its humus and which results in slow growth of trees.

Dr. Shaw--In the Piedmont area the growers have been spraying in full bloom to a considerable extent. In our mountain area spraying has not been used very much because fire blight is rare in that area. I expect it relates to fertilization. These orchards are not subject to cultivation readily and have not been fertilized heavily with nitrogen until recent years when growers have begun to seed their orchards with Lespedeza. This practice may bring a fire-blight problem there.

One phase of fire blight has been only touched upon; that phase is varietal resistance. Mr. Rankin, can you tell us about fire-blight resistance work in Pennsylvania?

Mr. Rankin--Some work has been done on disease-resistant varieties, but I do not know very much about the breeding work. Dr. Nixon has done this work in Pennsylvania. He has one pear, the Richard Peters, which is said to be very resistant and fairly early, earlier than the Kieffer. I would rather let Dr. Hildebrand make a statement about it.

Blight in Pennsylvania was worse in 1939 than it had been in many years. There is a question in my mind in taking the problem of control to the growers. The control program consists of general recommendations on canker eradication, trying out full-bloom sprays on susceptible varieties, rubbing off water sprouts, removal of old pear trees, modified cultivation and fertilization, and some other less important points. We encounter some problems in extension work which are rather hard to overcome. Canker removal is a problem. We can go into any orchard in Pennsylvania and find that Romes, Jonathan, Baldwin, or even such varieties as Golden Delicious have numerous cankers. Cankers sometimes hold over in Jonathan and Wealthy; but in many varieties even where there is abundant canker formation, there will be no winter hold-over. That brings up a question of just how far we can go in promoting canker removal. Grow-

ers think they are being misled when we recommend canker removal, and they do not remove the cankers and have no fire blight the next year. In a great many orchards, 10 to 15 years old, a number of trees are turning yellow and are dying. I have been told that a large percentage of this is caused by fire blight in the roots. I have examined some of the trees and found fire-blight cankers in the roots of some and none in others. The canker-removal problem is the one that bothers us most.

Dr. McCown--With regard to the so-called "full-bloom sprays," I think the terminology should be changed. It should be "early-blossom sprays" instead of "full-bloom sprays." I do not think we are justified in Indiana in recommending wholesale applications of early-blossom sprays because we must know the history of an orchard before we can tell a grower that he may expect results from an early application.

One of the biggest orchard-disease problems is the occurrence of apple scab, and in three seasons out of five the early-blossom spray is very important for the control of scab because we usually have rains at that time. Apples are just as susceptible to scab infection during the blossoming period as during the earlier or later development periods. We have to be practical, especially when orchardists are having a difficult time getting back more than they put into the orchard. I justify the spray more from a standpoint of scab control than for fire-blight control. In some seasons when the spray is applied at the proper time, control of both scab and fire blight is obtained. Weak bordeaux is one of the cheapest materials we have for this purpose.

Dr. Gardner--Zinc chloride is still being used as a canker disinfectant in California, but I do not have very much faith in it. We have tried several other things, but I cannot report on these except to say that spraying with an antagonistic organism has been tried.

Dr. Shaw--About the question of resistance to blight, Dr. Hildebrand, have you any comments on this problem?

Dr. Hildebrand--I think Dr. Nixon's resistant pear, Richard Peters, is a wonderful thing. Dr. Nixon sent material to me which I had inoculated at his planting at State College, Pa., and not a single bit of infection was noticed in any of the shoots which had been inoculated under ideal conditions. Numerous inoculations with 136 cultures were involved. Dr. Nixon has found that some blight will show up, but it does not go beyond blighting of the blossoms. I think the pear is a good one from the standpoint of blight resistance.

We do not recommend eradicating cankers as the only method of blight control. There is another approach, mentioned earlier, on the use of eradicant fungicides during the dormant season that is worth considering. One of the materials is 1-percent Elgetol (sodium salt of dinitro-orthocresol plus an oil organic penetrant) put on in the dormant season. Although only one season's observations are available, it is remarkable how few cankers survived the treatment. Eradicant fungicides also control the aphid which is one of the worst sucking insects. Elgetol is used in a water solution.

Dr. Cation--The Campas pear is very resistant in Michigan. I know of one orchard in which fire blight was severe last year. The blight went back in the tips of the twigs a short distance but did not go into the larger wood.

Dr. Shaw--There is one question I should like to ask the group. If we have a conference at our meeting next year, we would like to have suggestions of subjects to consider. Do you have any subjects that you would like to suggest to the committee?

Dr. R. J. Haskell (Washington, D. C.)--It seems to me that this has been a very worth-while discussion. We have had contributions from research and extension people. We have taken a single disease and considered it rather thoroughly. Perhaps next year we might take up some other disease problem and go into that in some what the same way. Sometimes we try to cover too much ground. Just at the present I have no specific topic to suggest.

Dr. Gardner--Will there be a mimeographed report of this meeting? I would appreciate having a copy of Dr. Keitt's paper and some of the various remarks, and if additional funds are needed I would be glad to help pay for it.

Dr. Shaw--A report will be mimeographed and published in the "Extension Pathologist."

I want to thank all who have taken part in this program, especially Dr. Hildebrand, Dr. Keitt, and all others upon whom I have called.

If there are no further comments the meeting stands adjourned.

EPIDEMIOLOGY OF FIRE BLIGHT OF APPLES AND PEARS^{1/}

G. W. Keitt
College of Agriculture, Madison, Wis.

When our chairman invited me to introduce the subject of epidemiology of fire blight of apples and pears, I asked him what type of treatment was desired, as it is obviously impossible to cover the entire subject in the time at our disposal. He suggested that I approach it in the light of my own experience, pointing out problems that seem to need clarification and seeking to elicit discussion, rather than sketching the whole field. This I shall try to do.

To me the most striking thing about fire blight is the great variability in its epidemiology and in the problem of its control under different regional, seasonal, and local conditions. This high degree of variability, perhaps, explains in large measure why, after nearly 60 years of study, both the epidemiology and control of fire blight remain baffling and full of uncertainties.

In a given season, blight may be severe in some regions and not in others. In some regions where it is severe, the disease may be manifest chiefly as blossom blight or twig blight or both, while in others it may severely affect the larger branches and roots as well. In one season in a given region or locality, the blight epidemic may be severe; and in the following year little or no disease may appear. In any season there may be great local variations in the development of blight in different orchards, in different parts of a given orchard, or even from tree to tree in a block.

One investigator may report that bacterial ooze from hold-over lesions was the chief source of primary inoculum in his experience, while another may record the occurrence of epidemic outbreaks in which no such inoculum was found. One worker may say that the worst blight epidemics in his experience occurred in wet periods; another may say that they occurred in dry periods. One may conclude that meteoric water was the chief agent for transmission of inoculum for blossom infection under the conditions he encountered; while another investigator may report that the role of meteoric water was minor under the conditions of his experience, in which insects were the important agents of dissemination. One worker may report excellent control of blossom blight by a single treatment in bloom with weak bordeaux mixture, without serious russetting of the fruit; another may record failure of control by two such applications, with severe russetting from a single treatment. One worker may think that anyone who obtained results in conflict with his own was in error, or worse. Yet, with a wider experience, either worker in each of the examples I have mentioned might obtain results that conformed with the other's.

How might epidemiological studies contribute to the clarification of such conflicting evidence and to the improvement of methods for fire-blight control? Would it be possible to analyze and record the

^{1/} No attempt has been made to document this informal discussion or to mention all the individual workers who have made valuable contributions to the subjects treated.

phenomena concerned so that an epidemic in one year or region could be compared with that of another and the reasons for the success or failure of control programs understood? We can scarcely expect our extension men to do this, but it would seem highly desirable that it be done if possible in some of the research programs on which the extension work is based. With rather limited time and resources, my co-workers and I have given some consideration to these questions. I shall now report briefly on the general aims and methods of this work (including unpublished studies made jointly with each J. A. Pinckard and S. S. Ivanoff).

We have sought to base our studies of the epidemiology and control of fire blight on two fundamental concepts: (1) The disease results from the interaction of a plastic pathogen and a plastic suspect, each varying under the influences of heredity and environment; and (2) the consequences of control measures vary with complex and changing conditions. In seeking a more adequate understanding and record of the cycle of development of the disease and the effects of control measures, work has been directed along two correlated lines: (1) field studies of the development and control of the disease in relation to the play of the natural environment, and (2) laboratory and greenhouse studies under partly controlled conditions to supplement and aid in interpreting the fieldwork. The field studies include records on seasonal development of (a) the pathogen, (b) the suspect, (c) the disease, (d) the effects of control measures, and (e) meteorological factors, such as rainfall, temperature, and relative humidity. Attention is also given to insect vectors and their activities. The laboratory work has been concerned with analytical studies on specific phases of the epidemiological and control problems, such as mode and abundance of overwintering of the pathogen, modes of transmission of the inoculum, modes of infection, factors influencing the transmission of the inoculum and the initiation of infection, and relations of environmental factors to the development of the disease.

Since it is impossible to report this work here in detail, I shall now briefly discuss some of the results in connection with certain epidemiological questions that constantly confront the extension pathologist. In so doing, I wish to make it very clear that I am not attempting to generalize. I shall report the results as obtained under the conditions encountered in our work, with the hope of eliciting discussion that will bring out the experience of others, whether it be like or unlike our own.

Overwintering of the pathogen and occurrence of the primary inoculum. The source and sometimes the quantity of primary inoculum are of great importance in relation to epidemiology of the disease and the problems and methods of control. Three major types of overwintering have been suggested: (1) in association with holdover lesions, (2) advancement of the disease from the South with the northward progress of the blooming season, and (3) in the beehive. Our experimental work (especially that of Brooks and Miller) has revealed an amount of inoculum in association with hold-over lesions that seems adequate to explain the initiation of epidemics in Wisconsin. In conformity with results of others, we have found the organism to over-winter in the living tissues near the margins of lesions on the larger branches. Brooks found that it also overwinters in association with apple-twigs lesions. The percentage of lesions that become hold-

overs varies greatly with conditions and is usually greater for limb cankers than blighted twigs. We have not found suspects other than cultivated apples or pears to be important hold-over sources in Wisconsin. Furthermore, we have commonly, though not invariably, found evidence that the chief source of primary inoculum tends to be in the orchard affected rather than in a neighbor's orchard.

Transmission of the primary inoculum. Several agents of external transmission of the primary inoculum have been reported, for example, insects, meteoric water, and man. Furthermore, internal transmission may be accomplished by progress of the bacteria from their overwintering position through the tissues of the suspect until the current season's growth is invaded. The manner of transmission may have a very important bearing on control. If it is internal, the chances of effective prevention by spray are decreased. Whether transmission is dominantly by insects or meteoric water might profoundly affect the objectives of a spray program. Under the conditions we have thus far encountered in Wisconsin, meteoric water appears originally to have been the most important agent for disseminating the primary inoculum.

Modes of penetration of the bacteria into the tissues of the suspect. The mode of entry of the bacteria into the tissues of the suspect is very important in relation to control measures. Penetration through insect punctures, for example, might call for a different defensive procedure than penetration through natural openings. It has been shown that the bacteria are generally capable of infecting susceptible tissues following entry through fresh wounds of various kinds. Under suitable conditions, blossoms and young tissues may be infected through their natural openings, such as nectaries, stomata, hydathodes, stigmas, and anthers. The types of penetration encountered in nature seem to vary greatly with conditions.

It was long assumed that penetration of blossoms through natural openings was accomplished exclusively by way of the nectaries. While this may be the most common avenue of entry, Miller, Tullis, Rosen and others have shown that under suitable conditions of moisture, penetration of young blossoms or leaves can occur freely by way of stomata. Shaw has shown that the intercellular moisture in the plant tissues has a great influence on susceptibility or resistance to blight infection. Rosen and Hildebrand have each recently studied blossom infection and reviewed its literature. They report that infection through stigmas, earlier reported by Pierstorff, and through anthers occurs freely under suitable conditions. While the possible modes of entry of the bacteria seem to have been well defined, further studies seem desirable for a better evaluation of their roles in nature. Moisture conditions as affecting both the mode of transmission of the inoculum and the susceptibility of the host would appear to play a very important part in determining the avenue of infection.

Occurrence of the secondary inoculum. The kind and quality of secondary inoculum is of great importance. It may occur in the nectar or pollen or in the diseased tissues or the ooze therefrom. If the weather is too dry the nectar may become too concentrated, as pointed out by

Thomas and Ark, to permit growth of the bacteria. Similarly, very dry weather may minimize the production of bacterial ooze. Moist conditions favor the development of an abundant secondary inoculum.

Transmission of the secondary inoculum and factors limiting secondary infection. One of the greatest variables in the epidemiology of fire blight is encountered in the modes of transmission of the secondary inoculum. The development of the disease and the problems of control may be greatly modified, depending on how this transmission is accomplished and on the play of factors limiting the initiation of secondary infection. It is known that the secondary inoculum may be transmitted by insects, meteoric water, wind, and man. Much uncertainty, however, attaches to the details and comparative roles of transmission by these agents; and the factors that limit secondary infection are not well understood. Dr. S. S. Ivanoff and I have given some attention to these questions, with special reference to blossom blight. I shall now briefly discuss some of our unpublished results.

Relations of nectar concentration to growth of *Erwinia amylovora* and infection of apple and pear blossoms. Beutler studied the sugar concentrations of various nectars and showed that in general the volume of nectar increased and its sugar concentration decreased with increase in relative humidity. Thomas and Ark considered nectar concentration in relation to nectarial infection of apple and pear blossoms. Cut blossoms were atomized with a suspension of *E. amylovora*. One lot was placed in an atmosphere of high humidity, and another was dried quickly and kept in the laboratory. The blossoms kept at high humidity blighted; the others did not. The authors proposed that increase in volume and reduction in concentration in nectar of apple and pear blossoms bears an important relation to increase of fire blight.

Experiments by Thomas and Ark, Hildebrand and Phillips, and Ark have shown that, in cultures in media containing different concentrations of the sugars commonly found in nectar (sucrose, dextrose, and levulose) the bacteria did not grow well except at concentrations characteristic of the lower and intermediate range found in natural nectar of apple and pear. This work was done in test tubes seeded with large numbers of bacteria.

Dr. Ivanoff and I experimented with droplets (1/400 cc.) of artificial nectar in Van Tieghem cells seeded with 15 to 30 bacteria each, seeking more nearly to simulate natural conditions. The optimal sugar (sucrose, dextrose, and levulose in proportions by weight of 8.5, 6.4, and 6.4, respectively) concentration for growth was 2 percent. Growth was greatly reduced at the 10-percent concentration, almost suppressed at 20 percent, and wholly suppressed at 30 percent. The bacteria survived 48 hours in similar drops containing 20-percent sugars, 24 hours in 30 percent, and less than 24 hours in 40 percent.

Abbe refractometer readings were made on apple and pear nectar from blossoms under varied conditions. The sugar concentration tended to vary inversely with relative humidity and, in a majority of the orchard readings, was above the concentration at which the bacteria will grow.

Apple and pear blossoms were inoculated under various recorded conditions by placing a small droplet of bacterial suspension (in water or artificial nectar at different concentrations) in the nectar. Infection occurred freely only when the sugar concentration of the nectar was in the lower range encountered in nature. Sharp inhibition of infection occurred at the lower intermediate concentrations. There was usually no infection at the intermediate or higher concentrations which predominated in the orchard readings. However, infection occurred if the concentrated nectar was diluted soon enough after inoculation.

These results give further indication that nectar concentration is an important factor limiting blossom-blight infection, especially the nectarial infection initiated by insect-borne inoculum. A fuller understanding of these questions, however, must be sought by experiments in which the insects themselves transmit the disease. Dr. Ivanoff and I have, therefore, made a beginning on studies in this field.

Transmission of fire blight by bees and its relation to nectar concentration of apple and pear blossoms. The pioneer investigations of Waite and later observations and experiments by many others have established beyond doubt that the honeybee and some other insects are capable of transmitting blossom blight of apple and pear. However, comparatively little work has been done on the details of this transmission or the factors that favor or limit it. It has been our purpose to contribute to a re-examination of these aspects of the problem in the light of recent information, especially in their relation to nectar concentration.

Fire blight of apple and pear was transmitted by bees from one blossom to another in controlled experiments in greenhouse and orchard. The bees were handled as nucleus hives in cloth cages in the greenhouse or individually in a specially designed wire cage.

Bees were attracted to blighted blossoms that had been inoculated 5 days before, and they transmitted the disease to healthy blossoms.

Contaminated bees freely transmitted blight to healthy blossoms when the sugar concentration of the nectar was in the lower range encountered in nature but not when it was in the medium or higher range.

In these experiments nectar concentration was an important factor in limiting blossom-blight transmission by bees. However, in many experiments in which the nectar was at a favorable concentration, little or no infection occurred after bees had sipped from it. It is apparent that other factors in addition to nectar concentration are important in limiting blossom-blight transmission by bees.

If there were not sharp limitations on the ability of bees to transmit blight, it would be difficult to understand how our apple and pear culture could survive. A clearer understanding of these limitations may be of value in defining objectives and developing methods of control.

The condition of the tree as a factor in epidemiology. It has long been recognized that trees in rapid growth and high vigor are especially

subject to fire blight. The condition of the trees has seemed to be an important factor in epidemiology in Wisconsin. Fire blight rarely occurs seriously in the Door County area, where the soils are light and often shallow. On deeper and more fertile soils nearby, blight is much more of a problem. Our worst epidemics have commonly been in orchards that had received nitrogenous fertilizer.

Conclusion. In opening this discussion on the epidemiology of fire blight, I have sought to invite attention to certain problems that confront us and to suggest some methods by which they may be approached. Obviously the task of solving them is primarily that of the research man. However, an understanding of these problems, their present status, and progress toward their solution is very much within the province of the extension pathologist. By a keen analysis of his own situations, he may not only advance the efficiency of his work, but by bringing his experience to the attention of his colleagues in research he may render them a very helpful service.
